DEMONSTRATION OF PORTFOLIO RISK ASSESSMENT FOR HUNTINGTON DISTRICT DAMS

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ABSTRACT

The objective of the Demonstration of Portfolio Risk Assessment (PRA) is to provide U.S. Army Corps of Engineers (USACE) staff with exposure to applying portfolio risk assessment techniques to dam safety assessment and prioritization decision-making. The lessons learned and experience gained during this PRA will be utilized to formulate future USACE policy for the use of risk assessment in the USACE Dam Safety Assurance (DSA) Program. The results will be used to direct future research efforts to expand and extend the existing risk assessment tools and procedures. Valuable insights will be derived in regard to the nature and significance of dam safety issues at the dams and the analysis can provide a possible basis for justifying and prioritizing dam safety investigations. The risk assessment process is not intended to make or prescribe dam safety decisions. These decisions will be made by the USACE. However, with the results of a PRA, the USACE is equipped to be in a better position to make informed decisions, especially for prioritizing further investigations and risk reduction measures

The demonstration project was based on current PRA practice as applied in the U.S. and Australia. Typical formats for risk assessment results were used and various risk-based criteria currently in use by the USBR, BC Hydro and ANCOLD were implemented on a reference (or comparative) basis for evaluation by the USACE. The Demonstration PRA was conducted at a "reconnaissance" level of detail. It was based primarily on available information (e.g. engineering reports, analyses, and monitoring records), regional estimates of flood and earthquake loading-annual exceedence probability (AEP) relationships, breach-inundation modeling and consequences assessment. For certain variables, reasonable assumptions were made, based on engineering judgment and experience. When the working model is implemented, additional supporting engineering analyses may be conducted at the discretion of the USACE to improve and refine those initial assumptions.

An A/E contractor and pertinent USACE team members prepared the report jointly. The report describes the Demonstration PRA process, and risk assessment inputs, results, findings and recommendations. Supporting analyses are described in appendices of the report.

INTRODUCTION

The Portfolio Risk Assessment (PRA) is a tool for dam owners and operators who are interested in reducing overall risk and liability in a cost effective manner. It is a fluid process that prioritizes and to a certain extent assists in the identification of potential construction activities, remedial investigations, studies, and analyses relating to dam safety. The PRA is a departure from traditional hazard assessments in that risk is actually quantified and applied with projected costs. The "buy-down" of risk is then addressed in a systematic fashion in lieu of discussing in abstract and anecdotal terms. This process provides an excellent basis for communicating potential liability to non-technical decision makers.

The U.S. Army Corps of Engineers (USACE) has recognized the potential value of the PRA process and recently funded demonstration studies in three Districts. PRA studies have been facilitated in Huntington, Fort Worth and Baltimore Districts with the aid of RAC Engineers and Economists through a contract administered by the Institute for Water Resources (IWR).

PROCESS

The Huntington District PRA was initiated through Engineering and Construction Division with support from the Operations and Planning elements. The District team was assembled from senior staff in the design fields of geotechnical, hydraulic, structural and mechanical engineering. A strong base of project history and technical knowledge has proven to be essential. Huntington District has designed and constructed a substantial portion of its projects within the last 30 years. Therefore, many members of the PRA team were able to apply first hand knowledge of the projects within the PRA.

During initial team working sessions, PRA team members identified the following expectations for the demonstration PRA:

1. A basis for prioritizing and justifying funding requests.
2. Strengthening recurrent dam safety activities such as emergency action plans, instrumentation, staff training, etc… through prioritizing and justifying changes.
3. Demonstrate risk assessment and portfolio risk assessments procedures to the Huntington District staff and develop uniform procedures that can be used by other Districts.
4. Facilitate an improved understanding and communication of project specific dam safety issues amongst District staff.
5. Provide a tool for communicating dam safety risks to stakeholders and cost sharing partners.
6. Provide a mechanism for capturing dam safety issues in the face of pending senior staff retirements.

7. Provide a program quality assurance review to identify issues that may have been overlooked in previous dam safety reviews.
8. A possible retrospective look at the priority and justification for District dams that are already in the Dam Safety Assurance (DSA) Program.

These objectives may vary from what a private dam owner, other Corps District or agency might consider. It was, and still is, the intent of Huntington District to gain as much from the PRA as possible.

Our experience has shown that the most important factor in conducting the PRA is keeping perspective. The study was conducted at the reconnaissance level with existing data and a heavy emphasis on professional judgment. As more refined data becomes available, the model can be updated yielding reliable output. Answers will change over time, so one can deduce that there is no absolute answer.

The PRA process that was implemented for the Huntington District comprises the following major parts, which are depicted in Figure 1:

1. Identification of decision framework
2. Engineering assessments
3. Risk assessment
4. Prioritization of remediation alternatives (risk reduction measures) and investigations.

Decision Framework

Understanding the decision framework is important for identifying PRA outcome "targets" that will provide benefits to a dam safety program and related "business" processes and other stakeholders. It is important that the targeting process and outcomes are designed to meet the owner's and other stakeholders' information needs at the onset of the PRA process. In addition, it is important that the PRA process is adapted to meet the specific information needs associated with each portfolio of dams rather than develop a standard set of outcomes.

The following documents are important for defining the decision framework for the USACE DSA Program:

1. ER 1110-2-1156 Dam Safety: Organization, Responsibilities, and Activities: *This regulation prescribes the policy, organization, responsibilities, and procedures for implementation of dam safety activities within the USACE.*
2. ER 111-2-1155 Dam Safety Assurance Program: *This regulation provides guidance and procedures for investigation justification of modifications for dam safety assurance at completed USACE projects.*
3. ER 1130-2-417 Major Rehabilitation Program and Dam Safety Assurance Program

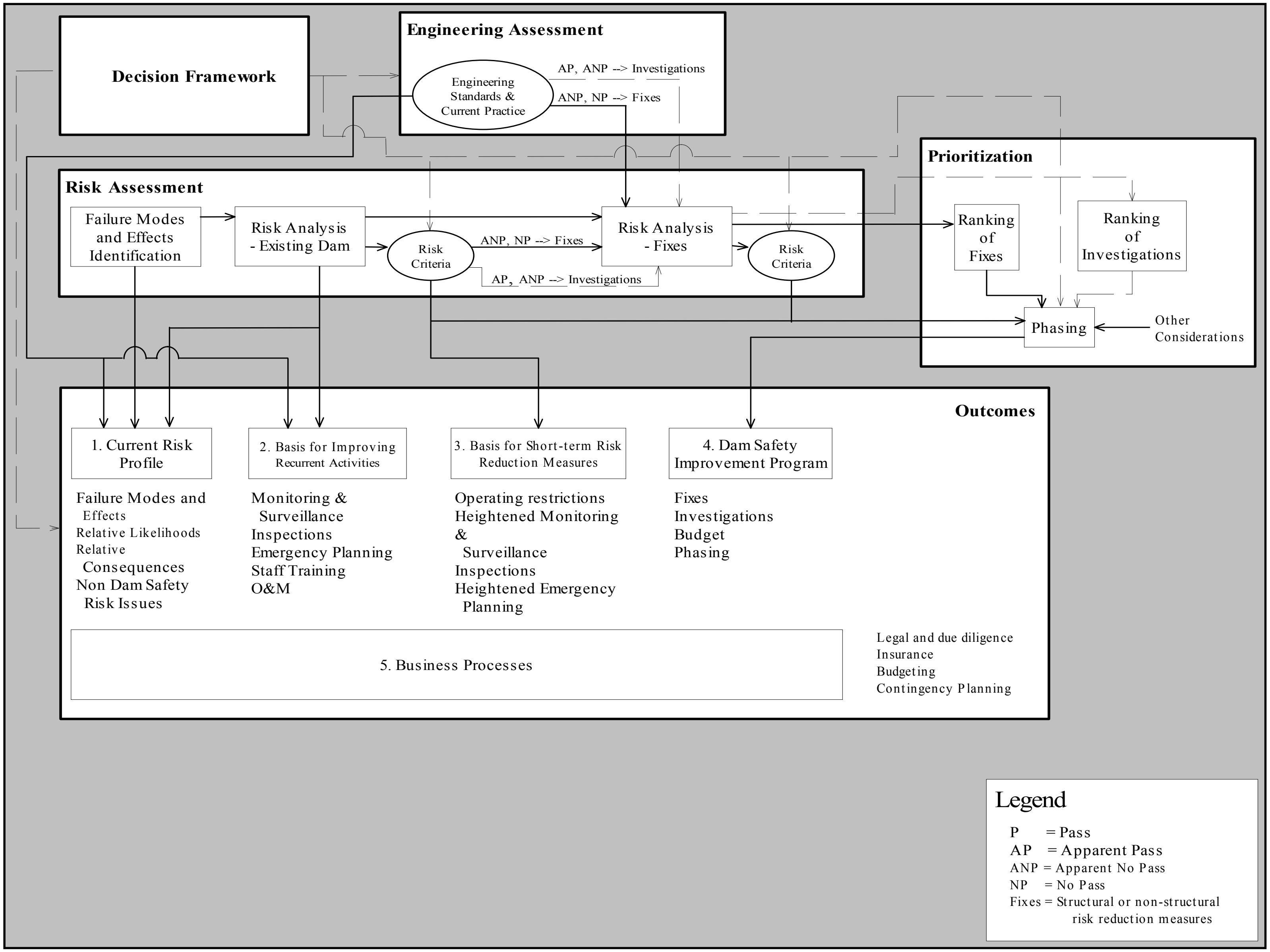

Figure 1. Portfolio Risk Assessment Process and Outcomes

In general, the Districts are responsible for preparing dam safety reports that are submitted to Headquarters in support of requests for DSA funding. Once approved, DSA funds cover design and planning of alternative solutions, but investigations in support of the preparation of these reports must come from Operation and Maintenance (O&M) funds controlled by the Districts. Large capital fixes that cannot be qualified under the DSA Program may be submitted under the Major Rehabilitation Program. Smaller capital fixes must be funded from the District's O&M funds. Thus, it is important to distinguish the funding source for fixes at USACE dams.

Engineering Assessments

The Huntington District's 35 high hazard dams were all considered in the engineering assessment tasks. These dams are listed in Table 1 with some general attributes, such as location, dam type and spillway type. The PRA dams are generally located within river basins that connect to the Ohio River. The major drainage systems are located to include the Muskingum, Hocking, and Scioto River systems in Ohio; The Big Sandy in Kentucky and along the West Virginia-Kentucky border; and the New and Kanawha, the Little Kanawha and Twelve Pole systems of West Virginia. The potential impacts of dam failure investigated in the study are thus located in the floodplains of these streams in Ohio, Kentucky, and West Virginia, although two of the impoundments are located in the higher elevations of Virginia just over the southeast border of Kentucky.

Engineering assessments indicate whether portfolio dams are expected to meet current USACE engineering practice, including documented standards and good USACE practice. They serve to initially identify potential remedial alternatives that will be evaluated using risk assessment and investigations that are needed to achieve adequate confidence in the onset assessments. A rating system was utilized as a means for summarizing the results of the engineering assessments and communicating them to decision makers. Ratings were assigned to the 35 Huntington District dams against of list of engineering factors. Assessment factors were grouped by types of initiating events and dam subsystems. The list of assessment factors was developed jointly by the Huntington District team and RAC. During the assessments, most criteria were rated for normal operating, flood and seismic (sunny day) conditions for a Pass (meet criteria), Apparent Pass (should meet criteria when formally evaluated), Apparent No Pass (should not meet criteria when formally evaluated), or a No Pass (does not meet criteria). Some criteria applied only to one or two conditions, but the overall effort was considerable in scope. In all, the team evaluated over 2,000 entries in the collective database. The entries were then reviewed and sorted; generating a short list of all projects with Apparent No Pass or No Pass screenings. This short list of 18 projects is what established the basis for the PRA proper.

Table 1. Selected Features of Huntington District High Hazard Dams

		General						Dam Information								Spillway Information		
A	B	C	D	E	G	H	I	K	L	S	T	U	V	W	X	AS	AW	AY
PROJECT	INCLUDED IN PORTFOLIO RISK ASSESSMENT	OFFICE SYMBOL	DSA PROJECT	STATE	RIVER	YEAR COMPLETED	YEAR MODIFIED	PURPOSE	DAM TYPE	DAM HEIGHT (FT)	STRUCTURAL HEIGHT (FT)	HYDRAULIC HEIGHT (FT)	LENGTH	MAXIMUM DISCHARGE (CFS)	MAXIMUM STORAGE (AC-FT)	SPILLWAY TYPE	SPILLWAY DISCH. (CFS)	SPILLWAY TYPE
Alum Creek Lake	No	ACS		OH	ALUM CREEK OF BIG WALNUT CRK.	1974	1978S	CSRF	zoned impervious w/ internal drains & concrete gravity spillway section	86.0	93.0	81.0	10,000	61500	134800	C	61500	CONCRETE, GATED
Atwood Lake	Yes	ATI		OH	INDIAN FORK OF CONOTTON CREEK	1936	1997F	CROF	rolled earth fill w/ impervious core	57.0	65.0	55.0	3,700	12800	49700	U	12800	ROCK CUT
Beach City Dam	No	BCS	A	OH	SUGAR CREEK OF TUSCARAWAS RVR	1936	1979F	CRO	rolled earth fill w/ impervious core	59.0	64.0	55.0	5,600	28000	71700	U	28000	ROCK CUT
Brewster Levee																		
Silica Sand Levee																		
Beech Fork Lake	Yes	BBF		WV	BEECH FORK OF TWELVE POLE CRK.	1976		CRF	rolled rockfill w/ impervious core & internal drains	65.3	86.0	58.0	1,080	29500	37540	U	28000	PAVED ROCK CUT
Bluestone Lake	Yes	BLN	A	WV	NEW RIVER	1947		CRF	concrete gravity	152.0	165.0	152.0	2,048	430000	631000	C	430000	CONCRETE, GATED
Bolivar Dam	Yes	BOS	C	OH	SANDY CREEK	1938	1982F;1989S;1989H	C	rolled earth fill w/ impervious core and 3.5' concrete parapet wall on crest	72.5	90.5	67.0	6,300	61700	149600	U	116000	ROCK CUT
Industrial Levees (2 @ Sparta)																		
Magnolia Levee		MAS																
Burnsville Lake	Yes	BUS		WV	LITTLE KANAWHA RIVER	1976	1978F	CROF	rolled rockfil, impervious core, internal drains; homogeneous impervious section & concrete gravity section	73.3	89.0	68.0	1,400	123500	65900	C	115000	CONCRETE, GATED
Charles Mill Lake	No	CMB	C	OH	BLACK FORK OF MOHICAN RIVER	1936	1985S;1995F	CRF	rolled earth fill w/ impervious core & 4.4' parapet wall along crest	43.0	52.0	38.0	1,390	23500	88000	U	23500	TERRACED, PAVED, GATED
Dike No. 1																		
Dike No. 2																		
Pavonia Levee																		
Clendening Lake	Yes	CLB		OH	BRUSHY FK OF STILLWATER CRK	1936	1971F;1975F;1979F;1982F	CROF	rolled earth fill w/ impervious core	64.0	64.0	57.0	950	13200	54000	U	13200	ROCK CUT
Deer Creek Lake	No	DCS		OH	DEER CREEK	1968		CROF	rolled earthfill w/ concrete gravity section & internal drains	86.0	93.0	81.0	3,880	117000	102540	C	112000	CONCRETE, GATED
Delaware Lake	Yes	DEO		OH	OLENTANGY RIVER	1948	1994S	CRSOF	rolled earth w/ impervious core, random shells & concrete gravity section	73.0	92.0	66.0	18,600	96000	132000	C	96000	CONCRETE, GATED
Waldo Levee																		
Dewey Lake	Yes	DEW	A	KY	JOHNS CREEK OF LEVISA FORK	1949	1987F	CROF	rolled earthfill	93.0	118.0	86.0	913	22800	93300	U	22800	ROCK CUT
Dillon Lake	Yes	DIL		OH	LICKING RIVER	1960	1996F	CROF	rolled earth fill w/ impervious core	95.4	118.0	90.0	1,400	89700	274000	U	89700	ROCK CUT
Nashport Dike																		
Pleasant Valley Dike																		
Dover Dam	Yes	DOT		OH	TUSCARAWAS RIVER	1938	1993F:1994F	C	concrete gravity	56.0	83.0	56.0	824	123000	203000	U	123000	CONCRETE, GATED
Corundite Levee																		
Fairfield Levee																		
Norton Chemical Levee																		
Somerdale Levee																		
Zoar Diversion Dam (Goose Pond)									rolled earth w/ impervious core		42.0		440.0					SOIL CUT
Zoar Levee																		
East Lynn Lake	No	ELT		WV	EAST FK TWELVEPOLE CREEK	1971		CRF	rolled rock w/ impervious core & internal drains	97.0	113.0	92.0	638	80300	82500	U	41100	ROCK CUT
Fishtrap Lake	No	FRL		KY	LEVISA FORK OF BIG SANDY RIVER	1969	1985S	CROF	rolled rock w/ impervious core & internal drains	158.5	195.0	152.0	1,190	298200	164360	C	298200	CONCRETE, GATED
Grayson Lake	No	GRL		KY	LITTLE SANDY RIVER	1968		CROF	impervious earthfill w/ DS random rock section	96.0	120.0	89.0	1,460	74600	118990	U	74600	ROCK CUT
John W. Flannagan	Yes	JWF		VA	POUND RIVER	1963		CRSOF	rolled rock w/ impervious core	241.0	250.0	236.0	916	246700	145700	C	246700	CONCRETE, GATED
Leesville Lake	No	LEM	C	OH	MCGUIRE CREEK	1937	1975F;1977F;1980F;1985H	CROF	rolled earth fill w/ impervious core	68.0	74.0	63.0	1,695	19700	37400	U	19700	ROCK CUT
Mohawk Dam	Yes	MKW	C	OH	WALHONDING RIVER	1937	1975F;1976F;1982F;1988H;1992H	C	rolled earth, gravel & rockfill with impervious core	110.0	111.0	105.0	2,330	151000	285000	U	151000	ROCK CUT
Mohicanville Dam	No	MOL	C	OH	LAKE FORK OF MOHICAN RIVER	1937	1984F;1985H	C	rolled earth fill w/ impervious core	39.0	46.0	36.0	1,220	20500	102000	U	20500	TERRACED, PAVED, GATED
North Branch of Kokosing River Lake	No	NBK		OH	NORTH BRANCH OF KOKOSING	1972		CROF	earthfill w/ internal drains	50.2	71.0	45.0	600	13500	14885	U	13500	PAVED SOIL OR ROCK W/ FLIP BKT
North Fork of Pound Lake	Yes	NFP		VA	NORTH FORK OF POUND RIVER	1966		CRSF	rolled rock w/ impervious core	100.0	122.0	95.0	1,400	43000	11293	U	43000	ROCK CUT
Paint Creek Lake	Yes	PCS		OH	PAINT CREEK	1973		CSROF	rolled rock w/ impervious core	103.7	118.0	99.0	700	204000	145000	C	204000	CONCRETE, GATED
Greenfield Levee																		
Paint Creek Dike																		
Paintsville Lake	No	PIV		KY	PAINT CREEK	1980		CROF	rolled rock w/ impervious core	139.0	160.0	134.0	1,660	48000	73500	U	48000	ROCK CUT
Piedmont Lake	Yes	PES	A	OH	STILLWATER CREEK	1937	1997F	CROF	rolled earth fill	47.0	56.0	45.0	1,750	15200	66700	U	15200	ROCK CUT
Auxiliary Spillway																		NATURAL SADDLE
Pleasant Hill Lake	Yes	PHC	A	OH	CLEAR FORK OF MOHICAN RIVER	1937	1995F	CROF	rolled earth fill w/ impervious core	99.0	113.0	97.0	775	19000	87700	U	19000	MORNING GLORY SHAFT
R.D. Bailey Lake	No	RDB		WV	GUYANDOT RIVER	1976	1983H	CROF	rolled rockfill w/ concrete face & DS toe drain	270.0	310.0	265.0	1400+	232400	203700	U	232400	ROCK CUT
Senecaville Lake	No	SES	C	OH	SENECA FORK OF WILLS CREEK	1937	1982F;1985F;1993H	CROF	rolled impervious fill w/ rock toe	36.8	45.0	28.0	1,350	11400	88500	C	11400	CONCRETE, GATED
Summersville Lake	No	SUM		WV	GAULEY RIVER	1965	1984H;1986H	CROF	rolled rock w/ impervious core	332.0	390.0	327.0	2,280	412000	413400	U	412000	ROCK CUT
Sutton Lake	No	SUT		WV	ELK RIVER	1960		CROF	concrete gravity	196.7	210.0	190.0	1,178	222240	265300	C	222240	CONCRETE, GATED W/FLIP BKT.
Tappan Lake	No	TAL	C	OH	LITTLE STILLWATER CREEK	1936	1975F;1978F;1982H	CROF	rolled earth fill w/ 2.4' parapet	50.1	52.0	45.0	1,550	23700	61600	U	23700	ROCK CUT
Tom Jenkins Dam	Yes	TJE		OH	EAST BR OF SUNDAY CK	1950	1993F	CRS	homogeneous earthfill	65.1	84.0	60.0	944	21300	26900	U	21300	ROCK CUT
Wills Creek Lake	No	WCW		OH	WILLS CREEK	1936	1989F	CROF	rolled earth fill w/ impervious core	67.0	87.0	65.0	1,950	45800	196000	U	45800	ROCK CUT
Yatesville Lake	Yes	YBC		KY	BLAINE CREEK	1988		CROF	rolled rock w/ impervious core	75.5	156.0	72.0	865	63000	83300	U	63500	ROCK CUT

Column:
K Purpose
- I Irrigation
- H Hydroelectric
- C Flood Control and Stormwater Management
- N Navigation
- S Water Supply
- R Recreation
- P Fire Protection, Stock, or Small Farm Pond
- F Fish and Wildlife Pond
- D Debris Control
- T Tailings
- O Other

Column:
L Dam Type
- RE Earth
- ER Rockfill
- PG Gravity
- CB Buttress
- VA Arch
- MV Multi-Arch
- CN Concrete
- MS Masonry
- ST Stone
- TC Timber Crib
- OT Other

Column:
I Year Modified
- S Structural
- F Foundation
- M Mechanical
- E Seismic
- H Hydraulic
- O Other

S Dam Height (FT) - vertical distance between the lowest point on crest and lowest point on original streambed
T Structural Height (FT) - vertical distance from the lowest point of the excavated foundation to the top of the dam
U Hydraulic Height (FT) - vertical distance from the maximum design water level and the lowest point in the original streambed
W Maximum Discharge (CFS) - at the maximum designed water surface elevation
X Maximum Storage (AC-FT) - total storage below the maximum attainable water surface elevation, including any surcharge storage
Y Spillway Type
- C Controlled
- U Uncontrolled

Risk Assessment

The risk assessment portion of the PRA is an essential step needed to provide a picture of the risks associated with the existing portfolio, the need for risk reduction, the potential level of risk reduction for each potential remediation alternative, and the need for additional investigations. The risk assessment provides information for decision making using risk in lieu of deficiencies against engineering criteria or current practice. However, this is not to say that acknowledged engineering criteria relative to quantitative deficiencies should be ignored.

Risk assessment includes the following steps for each dam:

1. Failure modes identification.
2. Risk analysis of existing dam.
3. Risk evaluation of existing dam.
4. Risk analysis of separable construction upgrade packages.
5. Risk evaluation of potential remediation alternatives.

Failure modes identification is the foundation upon which the risk assessment is built, and therefore should be carefully performed for each dam. It is also important to minimize inconsistencies in the risk analysis of different dams, to avoid distortions in risk comparisons and prioritizations.

The evaluation of existing dams may also lead to the identification of additional remediation alternatives or investigations that were not identified during the engineering assessments. The results of risk evaluation can be summarized using risk ratings and presented alongside engineering ratings for the existing dams and separable construction upgrade packages.

The Huntington PRA team RAC Engineers and Economists are in the process of finalizing the risk and event trees that could lead to catastrophic failure. Specifically, factors related to seismic failure, overtopping, failure due to embankment or foundation piping, external stability, spillway gate reliability, consequences of failure, human factors and warning times are all being considered.

The PRA team has identified construction projects and studies to reduce the level of risk associated with identified deficiencies. Upon completion of the finalized risk assessment, associated costs will be interjected for a more comprehensive comparison.

Prioritization of Remedial Alternatives

Prioritization calculations require that estimates of risk reduction be made for each potential remediation alternative. Since the calculated risk reduction depends upon the sequence of implementation of the alternatives and their sequence is in turn based on the cost effectiveness of risk reduction, these risk reduction calculations will necessarily be iterative. Typically, risk reductions are calculated for annualized life safety, economic/financial losses, and probability of dam failure; but they can be calculated for different ranges of magnitude of life loss or economical/financial losses.

The ultimate result or outcomes of the PRA will be a prioritized list of construction activities and investigations relating to dam safety activities. However, other identifiable products have already been realized such as:

1. A comprehensive database of engineering ratings and historical data for all 35 Huntington District flood control projects.
2. An identified short list of 18 projects with known suspected deficiencies.
3. A work plan for identifying populations at risk and potential damages with respect to probable maximum flood (PMF) events.
4. A work plan for identifying risk and probability factors for seismic events.
5. Probabilities of embankment failures due to piping (for 16 of 18 short listed projects with earthen embankments).
6. The identified issue of spillway gate reliability (not previously considered).
7. Re-assembled library of engineering reports and data.

For the first time, the Huntington District has a central database of engineering facts and issues for each project. Some of these issues had never been formally documented or discussed with the newer breed of engineers; therefore, the working of the process has proven to be quite beneficial.

EARLY APPLICATION

The Huntington District has already applied PRA insights into an existing project in the early stages of the DSA process. The issues of external stability and deficient instrumentation at Dover Dam quickly resurfaced through the process and are being addressed with existing funds. Dover Dam is a run-of-river concrete gravity dam constructed in the mid 1930's. External stability has been a concern of the project for a considerable time period; however, the overall perspective of the PRA has assisted the District in refocusing resources towards the stability question.

RECOMMENDATIONS AND CONCLUSIONS

Many Districts and governmental agencies are experiencing a mass exodus of experience and institutional/technical knowledge through retirement. It is recommended that all Districts take the first step in establishing the rating of their respective flood control projects against established engineering criteria. Take the time and resources to collectively assemble relevant information of the projects to initiate discussions which would be enlightening to give perspective to the overall DSA program.

Also, take the time and resources to emphatically emphasize the need for reconnaissance level thinking and application. Some of our less experienced team members were very reluctant to offer input that could be changed or refined at a later date. Teamwork and time management can be severely hindered when the big picture is lost, even for a fraction in time. Be consistent to keep data and judgment in relative perspective.

The Huntington District's application of the Portfolio Risk Assessment has already proven to be a worthwhile venture. The District is looking forward to finalizing the results and planning for our future.

REFERENCES

(1998). Bowles, D.S., L.S. Anderson, T.F. Glover, and S.S. Chauhan, Portfolio Risk Assessment: A Tool for Dam Safety Risk Management, Presented at 1998 USCOLD Annual Meeting and Lecture